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ULTRASONIC STUDIES OF O- AND P- NITROPHENOLS AT VARIOUS CONCENTRATIONS

Article Particulars

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Abstract

To study the ultrasonic parameters of Ortho and Para Nitrophenols in various concentrations at room temperature. This variation in structural formula gives rise to variation in their physical properties. It has been carried out and gives details about the determination of viscosity, density and the preparation of solutions of various concentrations. These O- and P- Nitrophenols have been studied at various concentrations by dissolving them in double distilled water. From the study of various parameters it can be concluded that the solute-solvent interactions of O- and P- Nitrophenols with water are prominent at 0.04M concentration. This discussion throws light on the solute-solvent behavior of Nitrophenol with water.

***Keywords**: Interferometer; Ostwald's Viscometer; Pulse-Echo Technique and Ultrasonic diffraction.*

Introduction

Ultrasonic waves can be generated by high frequency vibrations in crystals. Above 20 KHz is the Ultrasonic region. Ultrasound has many practical applications such as Sea sounding, Movement of Natural animals, Medical field, Industrial field and Home applications; Ultrasonic baths are used to clean metal, machine and jewellery. The high frequency (short wavelength) ultrasound vibrations loosen particles in otherwise inaccessible places. O-nitrophenol finds its applications in organic synthesis as an intermediate compound. It is also applied as a reagent for glucose and also used as an indicator. P-nitrophenol, like O-nitrophenol is utilized as an indicator and an intermediate compound in organic synthesis. It is used to produce parathion. It also acts as a fungicide in leather processing. In the present study, Ultrasonics has been utilized to study the ultrasonic parameters of O-and P-Nitrophenols at various concentrations by interferometer method.

Determination of Velocity of the Ultrasonic Waves in Various Techniques

As sound waves are mechanical waves, the velocity of it varies in different medium through which it passes and is of the order.

$V_S > V_L > V_G$ (Velocities in solid, liquid, gas medium)

Methods are

i) Using diffractrometer: This is used only for transparent liquids.
ii) Using interferometer: This can be used for all types of liquids.
iii) Using polycrystalline i.e., Pulse-echo technique: used to find ultrasonic velocity in solid medium.

Ultrasonic diffraction Method

Using sodium vapour lamp $\lambda = 5893Å$

$\lambda^1 = \lambda / \sin\theta$; $v = \upsilon\lambda^1$ (Velocity of Ultrasonic waves)

$U = 2Ln\lambda/d$ in the medium $2\theta = d/L$

d - Separation between two lines in cm.

L- Length of the telescope between the objective and the micrometer scale of the eye-piece.

Interferometer Method

$U = \upsilon\lambda$

U - Ultrasonic velocity and the various parameters of the organic compound.

(Ultrasonic Transducer using Micrometer Screw)

Pulse-echo Technique

To determine the elastic constants of a polycrystalline material (solid) using ultrasonic waves. A block of a poly crystalline material having perfect plane faces is taken and a crystal transducer "C" generating pulses of microsecond (µs) Order is kept in contact with a face so as to send ultrasonic waves in the block. Using two detectors D_1 and D_2 with respect to the face of crystal transducer "C" both the Longitudinal and Transverse waves are detected.

$v = 2L / t$

L - Linear dimension of the specimen along the direction of propagation of Ultrasonic waves.

t - Time taken by the waves to travel the specimen back and forth.

The density and temperature of the specimen is also noted. We can calculate the Lame constants µ and δ by the relations;

$V_l = \sqrt{\mu/\rho}$ $V_t = \sqrt{(\sigma + 2\mu)/\rho}$

$\eta = \lambda$ $\sigma = \delta/2\ (\delta+\mu)$

Ultrasonic Interferometer Method

$u = \upsilon\lambda$ $u = \sqrt{E/\rho}$

ρ - density of the crystal

E - Elastic constant

Ultrasonic velocity at these temperatures can be determined (In the test liquid).

Readings are noted for maximum deflection in micrometer screw, for each consecutive maximum and get the average value of λ/2. Ultrasonic wave velocity at various concentrations of the O- and P- nitrophenols in various ultrasonic parameters of these compounds are studied.

Preparation of Experimental Solution at Various Concentrations

$$Ws = \frac{\text{M.W x Volume required X Molar concentration}}{\text{Total volume of the liquid}}$$

X_s = (W/ molecular weight of the substance) x 1000)/ Weight of 5cc of water (m_1)

W = weight of salt for saturation = $m_2 - m_1$

m_1 - weight of 5 cc of water.

m_2 - weight of 5 cc of saturated solution.

Determination of density (ρ)

Using a specific gravity bottle the weight of empty specific gravity bottle is (m_1) determined using a chemical balance upto 0.0001gm.

$\rho = (m_2 - m_1)$/ Volume of specific gravity bottle (gm/cc)

ρ_1= 0.96176 gm/cc

m_2 - Bottle filled with distilled water and it is weighted in the balance (m_2)

ρ_1 = density of double distilled water

Volume of specific gravity bottle used was 25cc.

Determination of Viscosity(η)

Using Ostwald's viscometer, ρ_1, ρ_2 are densities of distilled water and test liquid respectively. η_{Water} - Viscosity of the distilled water and constant temperature. M and N glass bulbs fill up distilled water and liquid sucked up above the mark C. The liquid is allowed to flow through the capillary tube.

$\eta solu = \left(\frac{t2 \text{ X } \rho 2}{t1 \text{ x } \rho 1}\right) \text{X } \eta_{Water}$ centripoise ; η_{water} at 30°C = 0.7840

ρ_1= 0.96176 gm/cc

Ultrasonic Parameters

To determine the ultrasonic velocity (υ), density (ρ), viscosity (η) for various concentrations:

Ultrasonic Velocity (υ)

υ = 2n (λ/2) (cm/sec)

n - Frequency used

λ/2 - Average value

Specific Acoustic Impedance(Z)

$Z = \rho \upsilon$ Rayal

ρ - Density of the experimental liquid at various concentrations

υ - Ultrasonic velocity in the experimental liquid at various concentrations

Adiabatic Compressibility (β_s)

$\beta_s = 1/\upsilon^2 \rho$ (cm²/dyne)

Relaxation time (τ)

$\tau = 4\eta/3\rho\upsilon^2$ (seconds)

η - Viscosity of the experimental liquid at various concentrations.

Available Volume (V_a)

$V_a = M_{eff} / (\rho(1-\upsilon/\upsilon_a))$ cc

$M_{eff} = M_1 X_1 + M_2 X_2$

$X_1 = n_1/ (n_1+n_2)$; $X_2 = 1-X_1$

$n_1 = W_1/M_1$; $n_2 = W_2/M_2$

W_1 - Weight of solute

M_1 - M.W of solute (nitrophenol = 139.11)

M_2 - M.W. of solvent (water) = 18.016

W_2 - Weight of 100 ml solvent (water) = 100.36 gm.

υ_a - 1,60,000 (cm/sec)

Molar Compressibility (B) (or) Wada's Constant

$B = M_{eff} / (\rho\ (\beta_s)^{-1/7}$ $(cm^3/mol)/\ dyne\ cm^2)^{1/7}$

β_s - Adiabatic compressibility

M_{eff} - $M_{effective}$ value at various concentrations

Molar sound velocity (R) (or) Rao's constant

$R = (M_{eff} / \rho)\ \upsilon^{1/3}$ $(cm^3/\ mol)/\ (cm/s)^{1/3}$

Free Volume (V_f)

$V_f = (M_{eff}\ V)/(K\ \eta)$ ml/mol

V - Molecular weight / Density of the experimental solution

K - 4.28×10^9

Vanderwaal's Constant (b)

$b = (M_{eff}/\rho)\ ((1-(RT/ M_{eff}\ \upsilon^2))\ (1+ (M_{eff}\ \upsilon^2/3RT))^{1/2} -1]$ cm³/mol

$R = 8.314 \times 10^7$

T = Absolute temperature 30°C = 303K

Internal Pressure (Π_i)

$\Pi_i = [bRT(K\eta/\upsilon)^{1/2} (\rho)^{2/3}]/ M_{eff}^{7/6}$ Atmospheres

b = 2 (constant)

R = 8.314×10^7 (constant)

T = Absolute Temperature (303K)

K = 4.28×10^9 (constant)

Intermolecular Free length (L_f)

$L_f = K (\beta_s)^{1/2}$ Angstroms

K= 0.1998×10^{-5} (Temp. dependent constant)

Results and Discussion

Ultrasonic Velocity (υ)

Ortho-nitrophenol: It remains constant upto 0.03M. At 0.04M, it reaches a maximum value of 153898.46 cm/sec and thereafter decreases till 0.05M is reached.

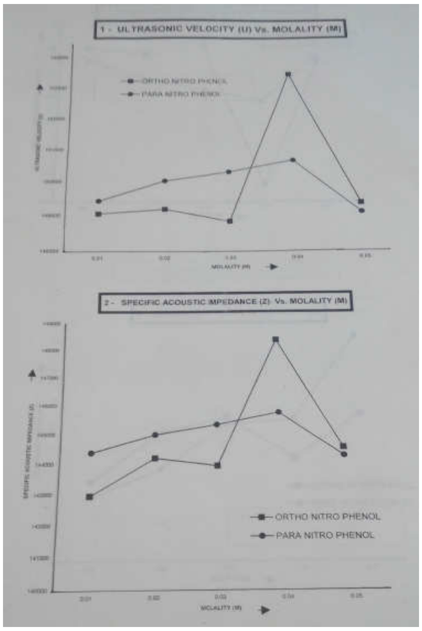
Para-nitrophenol: It is a gradual increase in velocity with increasing molarities. The velocity maximum at 0.04M and a gradual decrease is observed upto 0.05M.

These indicate that solute-solvent interactions in both the isomers.

Specific Acoustic Impedance (Z)

Ortho-nitrophenol: Acoustic impedance increases linearly with concentration, reaches a maximum at 0.04M and thereafter decreases.

Para-nitrophenol: A sudden increases in the value of the specific acoustic impedance especially at 0.02M and 0.04M.



Adiabatic Compressibility (β_s):

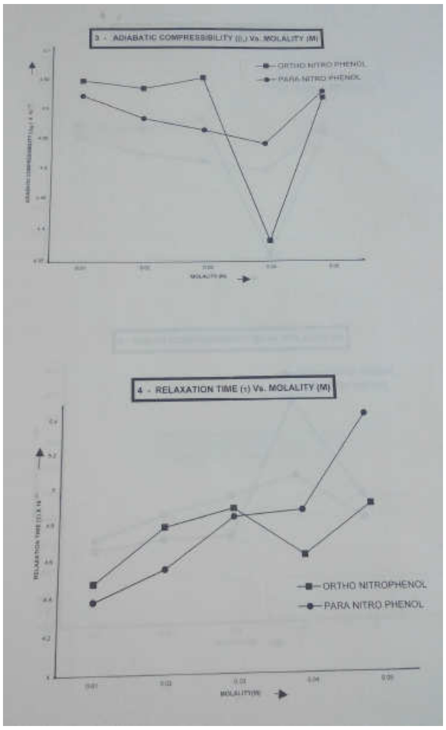
Ortho-nitrophenol: It remains almost constant upto 0.03M and there is a rapid decrease.

Para-nitrophenol: It gradually decreases and at 0.04M there is a small depression and afterwards there is a steep increase.

Relaxation time (τ):

Ortho-nitrophenol: It increases rapidly upto 0.02M. From 0.02 to 0.03 it increases gradually and then it decreases rapidly upto 0.04M and increases until 0.05M.

Para-nitrophenol: It increases gradually and attains maximum at 0.05M.



Available Volume (V_a)

Ortho-nitrophenol: It increases until 0.03M is reached and decrease at 0.04M.

Para-nitrophenol: It decreases upto 0.04M and there is a slight increase.

Molar Compressibility (B) (or) Wada's Constant

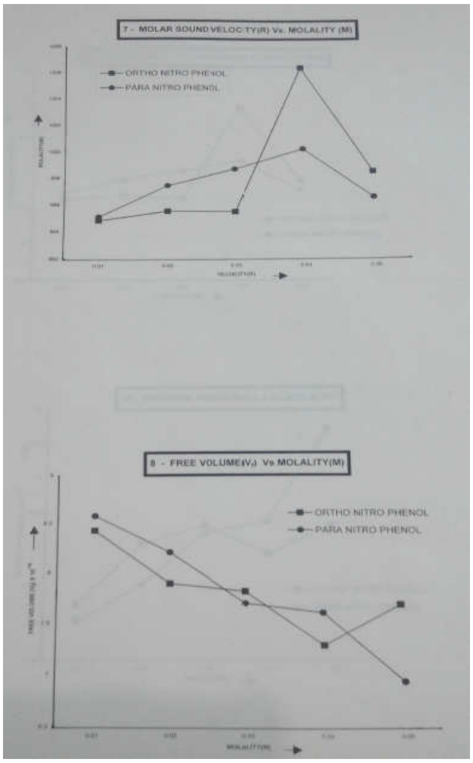
Ortho-nitrophenol: It slightly increases upto 0.03M and with a rapid increase in the value particularly at 0.04M.

Para-nitrophenol: It slightly increases until it reaches its maximum value at 0.04M and thereafter it decreases.

Molar sound velocity (R) (or) Rao's constant

Ortho-nitrophenol: It almost remains constant upto 0.03M and reaches its maximum value at 0.04M.

Para-nitrophenol: It increases with concentration upto 0.04M but it decreases as the concentration increases thereafter.



Free Volume (V_f)

Ortho-nitrophenol: It decreases rapidly upto 0.02M; from 0.03M to 0.04M, there is a steep decrease and it reverses its trend until 0.05M.

Para-nitrophenol: It gradual decrease of free volume upto 0.03M. from 0.03M to 0.04M it almost remains constant and decreases thereafter.

Vanderwaal's Constant (b)

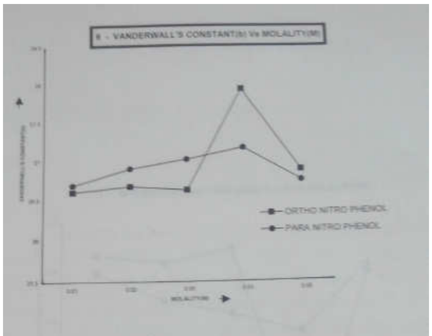
Ortho-nitrophenol: It remains almost constant upto 0.03M and it attains its maximum value at 0.04M. Thereafter it decreases rapidly until 0.05M.

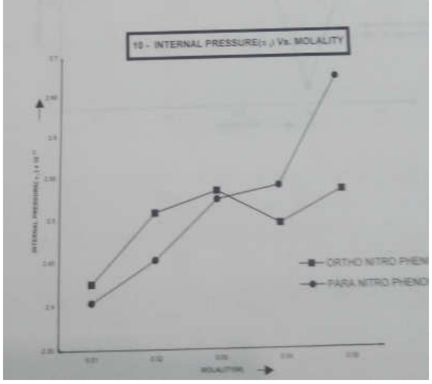
Para-nitrophenol: It gradual increase in Vanderwaal's constant it is maximum at 0.04M and there is a slight decrease until 0.05M is reached.

Internal pressure (Π_i)

Ortho-nitrophenol: It increases gradually and attains maximum at 0.05M.

Para-nitrophenol: It increases gradually upto 0.03M and the rate of increase is lesser until 0.04M.





Intermolecular Free length (L_f)

Ortho-nitrophenol: It slightly decreases upto 0.02M and then increases upto 0.03M. Thereafter there is a rapid decrease till 0.04M and then it increases as the concentration reaches 0.05M.

Para-nitrophenol: It gradual decrease upto 0.04M and attains a minimum value at 0.04M. Usually the intermolecular free length decreases as the concentration increases.

Conclusion

Isomers are substances with same molecular formula but different structural formulae. This variation in structural formula gives rise to variation in their physical properties. Of these O- and P- nitrophenols have been studied at various concentrations by dissolving them in double distilled water. Their ultrasonic parameters (11 Numbers) at the Room temperature have been studies and compared. From the study of various parameters it can be concluded that the solute-solvent interactions of O- and P- nitrophenols with water are prominent at 0.04M concentration. This discussion throws light on the solute-solvent behavior of nitrophenol (which finds various uses in many fields) with water.

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